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Altering microclimate of wheat (*Triticum aestivum* L.) by adjusting sowing dates, irrigation and nitrogen application in semi-arid and arid agroclimatic conditions of Punjab

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ABSTRACT

Field experiments were conducted during *rabi* seasons of 2017-18 and 2018-19 and results of both the years were pooled to evaluate the microclimate of wheat under five dates of sowing, two nitrogen and two irrigation levels at Ludhiana and Bathinda representing semi-arid and arid agroclimatic regions of Punjab. Soil temperature reported during seed emergence was maximum in early sown (20th October) crop and decreased with delay in sowing at both the locations under study. Canopy temperature from 60 DAS onwards was recorded lower in 5th November and higher in 20th December sown crop while in case of irrigation and nitrogen levels, it was lower under optimal irrigation (I_1) and recommended nitrogen (N_1) application. Stress degree days (SDD) calculated were also lowest in 5th November sown crop (-323.6°C) and these were lower in N_1 (-271.3°C) and I_1 (-274.9°C) during both the years, respectively. Better crop growth and hence, leaf area index resulted in higher PAR interception in October sown with optimal irrigation and recommended nitrogen level. Canopy temperature at different periodic intervals (75, 90, 105 and 120 DAS) showed negative correlation with grain yield (R^2 = 0.76, 0.75, 0.71 and 0.70, respectively). Similarly, SDD had negative relation with wheat yield (R^2 = 0.74).

Key words: Wheat, microclimate, date of sowing, irrigation, nitrogen

Agriculture is highly dependent on climatic conditions. Significant fluctuations and increased frequency of extreme weather events in the recent past have made it more vulnerable to climatic risks (Kingra and Kaur, 2017). Warmer temperatures and more extreme temperature events will significantly impact plant productivity. As *rabi* season crops are adapted to cooler conditions, thus greater losses are expected in *rabi* crops. Since rise in temperature is likely to reduce crop yield, thus it is imperative that suitable adaptation strategies have to be developed to minimize the adverse impacts. Thus, by making some adjustments in crop management, we can modify the crop microclimate without any significant financial burden, thus making it more favourable for growth and yield of the crops (Mahi and Kingra, 2013).

Matching the phenology of the crop to the duration of favourable environmental conditions by selecting the most appropriate sowing time to avoid the periods of stress is crucial for obtaining maximum yields under changing climate (Singh *et al.*, 2016). As the state of Punjab is suffering from large climatic fluctuations from last many decades (Kingra *et al.*, 2017) leading to significant fluctuations in wheat productivity every year (Kingra, 2016; Kingra *et al.*, 2018), thus there is a dire need to manage climate change impacts on wheat production to ensure food security and sustainability of natural resources in the region. In view of this, the present study was conducted to evaluate the microclimate of wheat under different sowing dates, nitrogen and irrigation levels to explore suitable strategies to minimise climatic risks in agriculture under semi-arid and arid agroclimates.

MATERIALS AND METHODS

Study area

The study was conducted at two locations in semi-arid (Ludhiana) and arid (Bathinda) agroclimatic regions of Punjab. Ludhiana is located at 30°54'N latitude, 75°54'E longitude and 247 meter altitude, whereas, Bathinda is located at 30˚36'N latitude, 74˚28'E longitude and 211 meter altitude above mean sea level. Both these locations have sub-tropical type of climate. The average annual rainfall is 755 and 400 mm at Ludhiana and Bathinda, respectively, about 75 per cent of which is received during south-west monsoon season (June to September). During winter months, the rainfall is received from western disturbances.

Experimental details

A factorial experiment was laid in split plot design at the research farm, Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana and Regional Research Station, Bathinda during *rabi* 2017-18 and 2018-19. Wheat variety HD-2967 was sown on five dates viz. 20th October (D_1), 05th November (D_2), 20th November (D_3), 5th December (D_4) and 20th December (D_5) (in main plots) with two nitrogen levels viz. N_1- Recommended dose of Nitrogen and N_2- 25 per cent less than recommended and two irrigation levels viz. I_1- Optimal (recommended) irrigation (Irrigation at CRI, Jointing, Flowering and Soft dough stage) and I_2-Sub-optimal irrigation (one less than recommended) (Irrigation at CRI, flag leaf emergence and soft dough stage) (in sub-plots).

Observations recorded

The soil temperature was recorded at 0730 and 1430 hrs during emergence of the crop by installing soil thermometers at 5 cm depth. Diurnal cycles of relative humidity were measured at two hourly intervals at tillering, booting and dough stages with the help of Belfort Psychron (Model 566 series) by keeping the instrument at the top of the canopy. Canopy temperature was measured at 1430 hours at 15 days interval with the help of Infrared Thermometer (FLUKE-574) starting from 45 DAS. Stress degree days were calculated following (Idso *et al.,* 1977) formula:

$$SDD = \sum_{i=1}^{n} (Tc - Ta)$$

Where, T_c is the canopy temperature (°C) and T_a is the air temperature (°C).

Diurnal cycles of photosynthetically active radiation (PAR) were recorded at two hourly interval from 0900 hours to 1700 hours at tillering, booting and dough stages. A Line Quantum Sensor (Model LI-190 SB) was used to measure the incoming, reflected and transmitted PAR in the range of 400-700 nm. These observations were then used to calculate the PAR interception (%) from the following formula:

$$\text{PAR interception (\%)} = \frac{\text{PAR (I)} - [\text{PAR (T)} + \text{PAR (R)}]}{\text{PAR (I)}} \times 100$$

Where, PAR (I) is PAR incident above the canopy, PAR (T) is PAR transmitted to the ground and PAR (R) is PAR reflected from the canopy

Regression analysis

Regression equations were developed to study the relation of canopy temperature at different periodic intervals and stress degree days with grain yield of wheat.

RESULTS AND DISCUSSION

Soil temperature

Among different sowing dates, soil temperature was observed higher in 20th October and lower in 20th December sown crop. At Ludhiana, soil temperature in D_1 was 18.0˚C, whereas in D_5 it was 7.4˚C at 0730 hrs. While, at 1430 hrs, it was 29.6˚C in D_1 and 17.8˚C in D_5. Similarly at Bathinda, the soil temperature in D_1 was 18.5 and in D_5 it was 7.5˚C at 0730 hrs, while, at 1430 hrs, it was 30.0˚C in D_1 and 18.1˚C in D_5 (Figs. 1 & 2). Higher soil temperature under earlier sowing might have proved beneficial for better crop establishment and growth. Lafond and Fowler (1989) reported more uniformity and less emergence time for each degree rise in soil temperature from 5 to 20°C.

Canopy temperature (T_c) and stress degree days (SDD)

Among different dates of sowing, canopy temperature was observed lowest in 5th November and significantly higher in 20th December sown crop from 60 through 120 DAS at both the locations. Canopy temperature was 15.6°C at 60 DAS, whereas it was 18.5°C at 120 DAS in 5th November sown crop (Table 1). However, in 20th December sown crop, it was 21.0°C at 60 DAS and 26.5°C at 120 DAS indicating higher intensity of terminal heat stress with delay in sowing, which might have adversely affected wheat yield. Singh *et al*. (2016) also highlighted the role of earlier sowing of wheat in managing heat stress. Significantly lower canopy temperature was observed under recommended nitrogen application (N_1) and optimal irrigation (I_1). Similar results were also observed by Kingra *et al* (2013).

During both the years, the SDD were significantly lowest (-323.6°C/day) in 5th November sown crop and significantly highest in 20th December (-186.1°C/day) sown crop indicating increase in heat stress with delay in sowing (Table 2). In case of nitrogen and irrigation

Table 1: Variation in canopy temperature (˚C) under different dates of sowing, nitrogen and irrigation levels at Ludhiana (pooled data of *rabi* 2017-18 and 2018-19)

Treatment	Days after sowing					
	45	60	75	90	105	120
Dates of sowings						
October 20	18.4	16.2	15.9	14.3	17.7	19.5
November 5	17.6	15.6	15.4	13.5	16.7	18.5
November 20	19.6	18.2	17.4	16.3	20.5	22.6
December 5	15.3	19.4	18.8	17.5	21.3	24.6
December 20	17.1	21.0	20.2	19.5	23.7	26.5
CD (p=0.05)	0.3	0.4	0.4	0.3	0.2	0.2
Nitrogen levels						
Recommended (125 kg/ha)	17.8	18.2	17.7	16.3	20.1	22.5
25% less than recommended	17.4	17.9	17.4	16.1	19.8	22.2
CD (p=0.05)	0.1	0.1	0.1	0.1	0.1	0.1
Irrigation levels						
Optimal irrigation	17.9	18.4	17.9	16.5	20.3	22.6
Sub-optimal irrigation	17.3	17.8	17.2	15.9	19.7	22.1
CD (p=0.05)	0.1	0.1	0.1	0.1	0.1	0.1

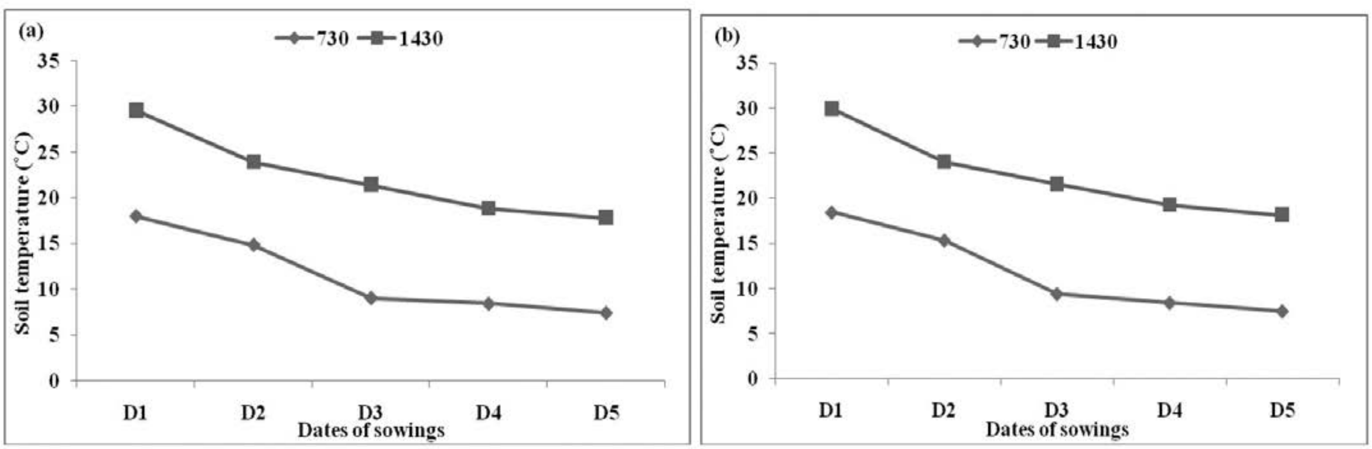

Fig 1: Soil temperature under different dates of sowing at 0730 and 1430 hrs during emergence of wheat at (a) Ludhiana and (b) Bathinda (data pooled over *rabi* 2017-18 and 2018-19).

treatments, SDD were lower under recommended nitrogen application (N_1) (-271.3°C) and optimal irrigation (I_1) (-274.9°C) during both the years as a result of better crop growth under higher nitrogen and irrigation application resulting in cooler canopy temperature. Similar results were also reported by Kaur *et al*. (2018). Both canopy temperature and stress degree days depicted negative correlation with grain yield (r = -0.78 for canopy temperature and -0.88 for stress degree days) in pooled data of 2017-18 and 2018-19, respectively (Table 2).

Relative humidity (RH)

Significantly higher RH was found in the case of 20th Oct. followed by 5th Nov., 20th Nov., 5th Dec. and lowest in 20th Dec. sown crop at both the locations (Tables 3 & 4). Among stages, it was highest at booting followed by tillering and was lowest at dough stage. In case of nitrogen levels, RH was more in N_1 as compared with N_2, which might be due to more vegetative growth in case of N_1. Among the irrigation levels, RH was higher under optimal irrigation (I_1) at all the growth stages, which might be due to lower canopy temperature and hence, more availability of moisture under I_1 treatment. Kumar *et al*. (2017) also reported significant effect of relative humidity on wheat yield.

PAR Interception

At tillering stage, PAR interception (%) was observed to be lower than booting as it increased with increase in leaf area index of the crop (Table 5). At booting stage, PAR interception was observed to be statistically highest due to higher leaf area index in 20th October sown

Table 2: Variation in average canopy temperature (T_c) and stress degree days (SDD) under different dates of sowing, nitrogen and irrigation levels at maturity at Ludhiana (pooled data of *rabi* 2017-18 and 2018-19)

Treatment	Average T_c (ºC)	Stress degree days (ºC/day)
Dates of sowings		
October 20	17.0	-314.2
November 05	16.2	-323.6
November 20	19.1	-271.2
December 05	19.5	-226.3
December 20	21.3	-186.1
CD (p=0.05)	0.30	5.43
Nitrogen levels		
Recommended (125 kg/ha)	18.8	-271.3
25 % less than recommended	18.5	-257.2
CD (p=0.05)	0.11	3.18
Irrigation levels		
Optimal irrigation	18.9	-274.9
Sub-optimal irrigation	18.3	-253.6
CD (p=0.05)	0.11	3.18
Correlation with grain yield	**-0.78**	**-0.88**

crop (84.6%) followed by 5th November (83.8%) and was lowest in 20th December (73.8%) sown crop. Among nitrogen and irrigation levels, crop having recommended nitrogen (N_1) and optimal irrigation (I_1) captured more radiation, which might be due to better crop stand and hence higher leaf area index leading to more PAR interception. At booting stage, PAR interception was 80.7% under N_1 and 79.6% under N_2 level. Similarly at booting stage, higher PAR interception was observed under I_1 (81.3%) than under I_2 (79.0%). Pradhan *et al*. (2018) also observed more PAR interception and radiation use efficiency under higher nitrogen.

Relationship of canopy temperature and stress degree days with grain yield

Regression relationship developed between canopy temperature at different periodic intervals viz. 75, 90, 105 and 120 DAS and grain yield of wheat was observed to be significantly negative with R^2 = 0.76, 0.75, 0.71 and 0.70, respectively (Fig. 3) indicating that increase in canopy temperature by 1ºC at 75, 90, 105 and 120 DAS could decrease grain yield of wheat by 2.1, 1.7, 1.4 and 1.2 q/ha. Similarly, stress degree days also had negative relation

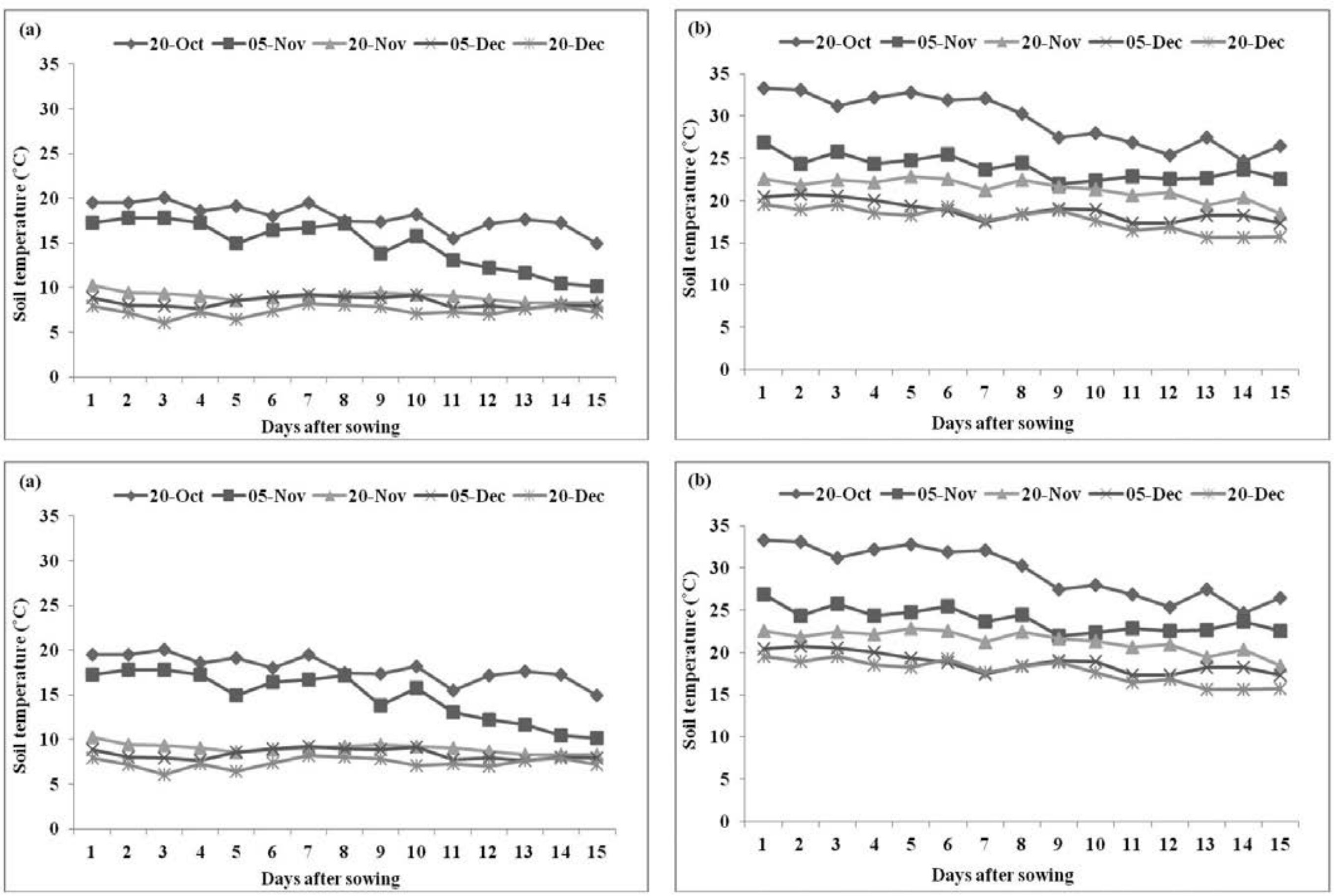

Fig 2: Soil temperature under different dates of sowing at 0730 and 1430 hrs during emergence of wheat (a & b) at Ludhiana and (c & d) at Bathinda (data pooled over *rabi* 2017-18 and 2018-19).

Table 3: Variation in relative humidity (%) under different dates of sowing, nitrogen and irrigation levels at Ludhiana (pooled data of *rabi* 2017-18 and 2018-19)

Treatment	Phenological stages											
	Tillering				Booting				Dough			
	1000	1200	1400	1600	1000	1200	1400	1600	1000	1200	1400	1600
Dates of sowings												
October 20	77.1	71.9	69.2	74.0	84.0	76.9	75.0	81.5	72.9	65.1	63.6	69.0
November 5	76.2	71.4	68.9	73.4	82.6	76.4	72.6	80.4	69.2	62.5	60.1	66.6
November 20	68.5	61.8	60.2	66.2	76.9	68.9	67.5	74.6	61.2	52.6	51.1	58.6
December 5	62.8	55.2	53.8	61.2	69.4	59.7	58.5	64.5	53.6	46.9	45.0	50.0
December 20	53.4	47.4	46.1	51.1	60.5	53.2	51.7	58.4	47.7	40.3	37.3	44.9
CD (p=0.05)	0.7	1.0	1.0	0.9	0.5	0.9	0.9	0.5	0.7	0.5	0.8	1.1
Nitrogen levels												
Recommended (125 kg/ha)	68.2	62.1	60.2	65.7	75.2	67.6	65.6	72.4	61.5	54.1	52.0	58.3
25% less than recommended	67.0	60.9	59.1	64.6	74.1	66.5	64.5	71.4	60.4	52.9	50.9	57.3
CD (p=0.05)	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Irrigation levels												
Optimal irrigation	68.8	62.7	60.7	66.4	75.8	68.1	66.1	72.9	62.0	54.6	52.5	58.9
Sub-optimal irrigation	66.4	60.3	58.5	64.0	73.5	66.0	64.0	70.9	59.9	52.4	50.3	56.7
CD (p=0.05)	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1

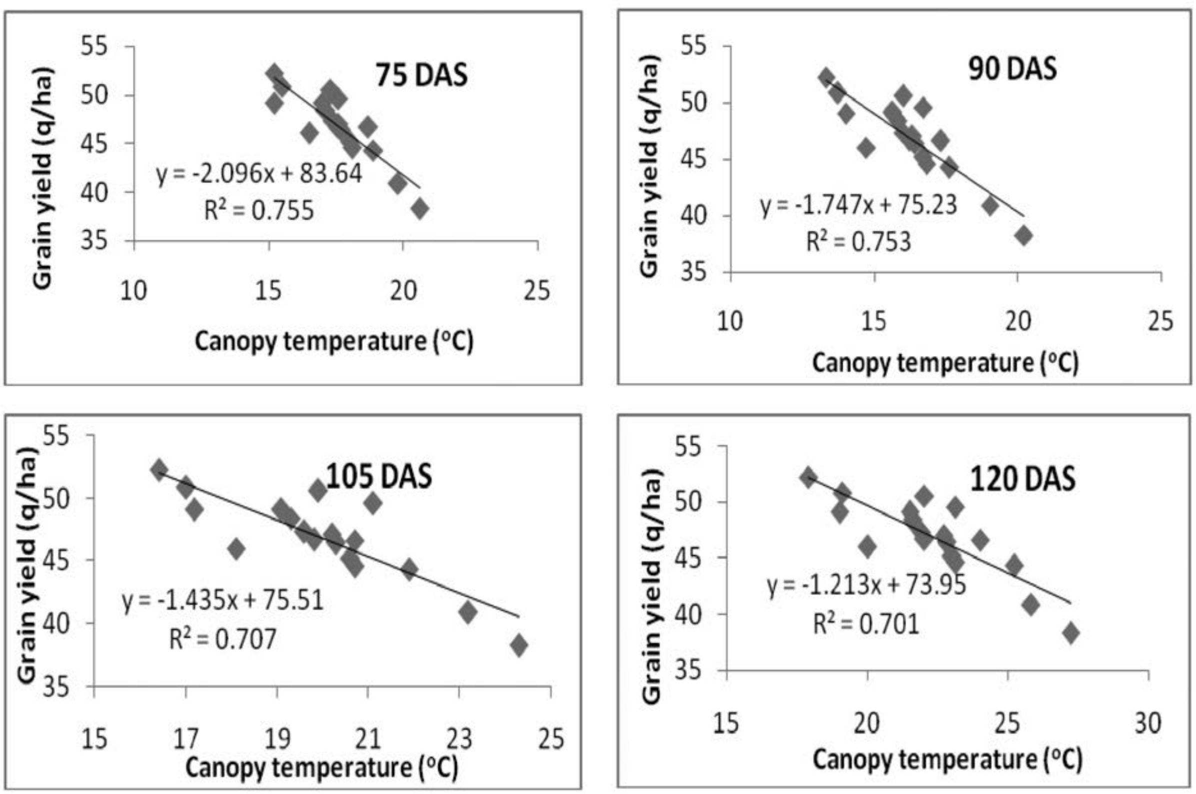

Fig 3: Effect of canopy temperature on grain yield of wheat

with grain yield of wheat (R^2 = 0.74) (Fig. 4) indicating the adverse effect of warming on wheat productivity. Similar results were reported by Kingra *et al*. (2010).

CONCLUSION

The study concluded that warming scenarios can have detrimental effect on wheat growth and productivity under semi-arid as well as arid agroclimatic conditions. However, microclimatic modifications through change in date of sowing as well as irrigation and fertiliser management can prove effective adaptive strategies to manage extreme weather vulnerability and climatic risks in field crops.

Table 4: Variation in relative humidity (%) under different dates of sowing, nitrogen and irrigation levels at Bathinda (pooled data of *rabi* 2017-18 and 2018-19)

Treatment	Phenological stages											
	Tillering				Booting				Dough			
	1000	1200	1400	1600	1000	1200	1400	1600	1000	1200	1400	1600
Dates of sowings												
October 20	75.2	69.2	65.2	72.0	81.1	75.6	71.7	79.0	69.6	62.3	59.4	67.7
November 5	74.2	67.2	66.3	72.2	79.1	71.6	69.0	75.5	67.3	59.9	57.5	65.2
November 20	68.2	62.6	60.9	65.9	76.6	69.5	67.9	74.7	58.3	51.9	50.0	55.9
December 5	61.1	54.0	52.7	59.6	66.3	59.5	58.9	65.3	52.0	44.4	42.7	49.4
December 20	52.1	47.6	45.7	50.3	59.0	54.0	52.4	58.0	44.8	38.6	38.2	42.2
CD (p=0.05)	0.4	0.8	1.3	0.3	0.9	0.3	0.4	1.1	0.8	0.8	2.4	1.3
Nitrogen levels												
Recommended (125 kg/ha)	66.7	60.7	58.8	64.6	73.1	66.6	64.5	71.6	58.9	51.9	50.7	56.6
25% less than recommended	65.6	59.5	57.6	63.4	71.8	65.5	63.4	69.4	57.8	50.9	48.4	55.5
CD (p=0.05)	0.2	0.2	0.1	0.1	0.3	0.2	0.1	0.2	0.2	0.1	0.2	0.1
Irrigation levels												
Optimal irrigation	67.2	61.3	59.3	65.1	73.7	67.1	65.0	71.6	59.4	52.4	50.2	57.2
Sub-optimal irrigation	65.1	59.0	57.1	62.9	71.2	65.0	62.9	69.4	57.3	50.4	49.0	54.9
CD (p=0.05)	0.2	0.2	0.1	0.1	0.3	0.2	0.1	0.2	0.2	0.1	0.2	0.1

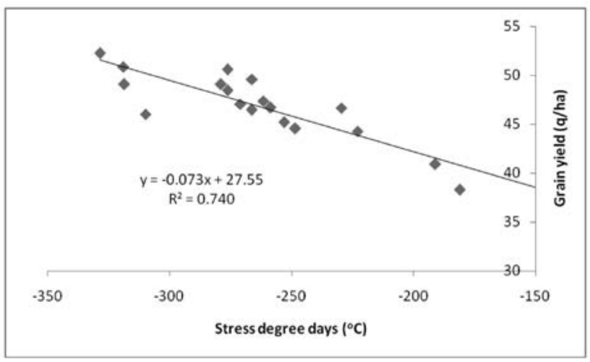

Fig 4: Relation between stress degree days and grain yield

Table 5: Variation in PAR (%) under different dates of sowing, nitrogen and irrigation levels at Ludhiana (pooled data of *rabi* 2017-18 and 2018-19)

Treatment	Phenological stages											
	Tillering				Booting				Dough			
	1000	1200	1400	1600	1000	1200	1400	1600	1000	1200	1400	1600
Dates of sowings												
October 20	77.4	79.7	75.4	71.3	82.1	84.6	80.7	75.0	71.5	76.6	72.2	66.8
November 5	77.2	79.2	74.4	70.3	81.7	83.8	79.4	73.6	70.8	75.3	71.7	66.5
November 20	74.5	76.6	72.5	67.7	78.6	81.0	76.8	71.0	69.7	73.4	68.0	63.3
December 5	68.7	72.3	68.0	62.3	73.6	77.6	74.9	67.6	64.1	70.0	62.5	57.6
December 20	65.3	68.8	63.5	55.6	71.3	73.8	71.4	64.1	60.3	64.7	61.4	53.8
CD (p=0.05)	0.4	0.5	0.9	0.6	0.4	0.7	0.8	0.4	0.5	0.4	0.9	0.7
Nitrogen levels												
Recommended (125 kg/ha)	73.2	75.9	71.3	66.0	78.0	80.7	77.2	70.8	68.0	72.6	67.7	62.2
25% less than recommended	72.1	74.7	70.2	64.8	76.9	79.6	76.0	69.7	66.6	71.4	66.6	61.1
CD (p=0.05)	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
Irrigation levels												
Optimal irrigation	73.7	76.5	71.8	66.6	78.6	81.3	77.8	71.4	68.4	73.1	68.2	62.7
Sub-optimal irrigation	71.5	74.1	69.6	64.2	76.3	79.0	75.5	69.1	66.2	70.9	66.1	60.5
CD (p=0.05)	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1

Conflict of Interest Statement : The author(s) declare(s) that there is no conflict of interest.

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